High Level Architecture

Federation Development and Execution Process (FEDEP) Model

Version 1.5

December 8, 1999

DMSO

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (FROM - TO)
08-12-1999		xx-xx-1999 to xx-xx-1999

4. TITLE AND SUBTITLE
High Level Architecture Federation Development and Execution Process (FEDEP) Model. Version 1.5
Unclassified

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME AND ADDRESS
Defense Modeling and Simulation Office
1901 N. Beauregard St., Suite 500
Alexandria, VA22311-1705

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS
United States Department of Defense
Defense Modeling and Simulation Office
1901 N. Beauregard St., Suite 500
Alexandria, VA22311-1705

10. SPONSOR/MONITOR'S ACRONYM(S)
11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APUBLIC RELEASE
,

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Department of Defense (DoD) High Level Architecture (HLA) has been designed to facilitate interoperability among simulations and to promote reuse of simulations and their components.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE	Public Release	32	Fenster, Lynn lfenster@dtic.mil
Unclassified	Unclassified	Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007

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FOREWORD

The Department of Defense (DoD) High Level Architecture (HLA) has been designed to facilitate interoperability among simulations and to promote reuse of simulations and their components. The HLA is composed of three major components:

- *HLA Rules*: A set of ten basic rules that together describe the general principles defining the HLA.
- *HLA Interface Specification*: A description of the functional interface between simulations (federates) and the HLA Runtime Infrastructure (RTI).
- *HLA Object Model Template (OMT)*: A specification of the common format and structure for documenting HLA object models.

In an HLA application, any number of physically distributed simulation systems can be brought together into a unified simulation environment to address the needs of new applications. These types of environments are known as HLA *federations*. The HLA specifications together define an overarching framework for the construction and execution of federations.

Within the DoD and other government and commercial organizations, many different approaches to project management and systems engineering are being used. Such practices, procedures, and methodologies have evolved over time based on how well they serve the different functional areas and user communities for which they are intended. Many of these approaches currently use modeling and simulation (M&S) as a key enabler of certain functions, such as concept evaluation, testing, and training. However, few application areas have yet determined how to tailor their native management and engineering processes to take advantage of HLA. For instance, while many in the analysis community have established procedures for non-runtime exchange of data from one simulation to another, the opportunities provided by HLA for more dynamic exchange of data at runtime requires that existing engineering processes be modified or augmented in order to take advantage of such opportunities. Even in communities in which distributed simulation is more commonplace (e.g., training), migration to HLA generally requires some modification to existing management and engineering processes to capture the benefits offered by HLA. As simulation users begin this migration, it is critical that guidance be available to orient new users to the specific set of tasks and activities necessary to develop HLA federations.

This document describes the HLA Federation Development and Execution Process (FEDEP) Model. The purpose of this document is to describe a generalized process for building HLA federations. It is not intended to replace the existing management and engineering processes of HLA user organizations, but rather to provide a high-level framework for HLA federation construction into which lower-level development practices native to each individual application area can be easily integrated. In addition, the HLA FEDEP is not intended to be prescriptive, in that it does not specify a "one size fits all" federation development process for all HLA users. Rather, the FEDEP defines a generic, common sense systems engineering methodology for HLA federations that can and should be tailored to meet the needs of individual applications.

Although every HLA application requires a basic agreement among all federates as to the systems engineering approach that will be used to develop the federation, there can be significant variability in the degree of formality defined in the chosen process. The primary driver for how much formality is required is the size and complexity of the application. For example, in large complex applications with many distributed federates, project control requirements generally dictate the need for a rigidly defined, highly structured federation development process to ensure proper communication and coordination among all team members. In such federations, requirements and associated schedules for delivery of federation products are generally very explicit, as is the content and format for documentation of these products. In smaller or less complex applications, a less structured process with fewer constraints on the types, formats, and content of federation products may be perfectly reasonable and may have certain efficiency advantages as compared to a more formalized process.

Other secondary factors may also drive the federation development process selected for a specific application. For instance, some communities may have documentation requirements that are unique to their application area. In this case, the federation development activities required to produce these products must be accounted for in the overall process. The reuse potential of these and other required federation products may also influence the nature and formality of the activities that produce them. Another factor is the availability of reusable federation products and persistent federation development teams, as opportunities for shortcuts and thus a more streamlined, efficient development process may be identified and taken advantage of. Finally, practical resource constraints (i.e., cost, schedule) may dictate how certain federation development activities are performed and how the associated federation products are produced and documented.

In summary, it is recognized that the needs and requirements of the distributed simulation community are quite diverse. The HLA provides a generalized architecture for simulation

interoperability; however, strict adherence to the HLA specifications is not, by itself, sufficient to ensure a fully consistent, interoperable distributed simulation environment. For instance, issues such as the need for consistent environmental databases and for consistent behavior representations of objects modeled by more than one federate are critical to achieving interoperability; however, these types of issues cannot be fully addressed solely through adherence to the HLA specifications. Although some technical or managerial issues may be unique to a given application, many other issues associated with building a fully interoperable HLA federation are more general in nature. The HLA FEDEP, in conjunction with the FEDEP Checklists (separate document), are offered to the HLA community as a starting framework for identifying and addressing these more general issues, as discussed within the context of a full end-to-end process model for the development of distributed simulation environments (federations) that fully conform with the HLA specifications. This framework can and should be tailored as appropriate to address the unique issues, requirements, and practical constraints of each individual application. It is expected that this framework will provide a viable foundation for all HLA applications and will assist the users in defining the specific tasks and activities necessary to support their particular needs.

RELATED DOCUMENTS

The three specifications that together compose the HLA provide the technical foundation for designing and developing all HLA federations. These specifications are described in the following documents:

- **HLA Rules V1.3**
- **HLA Interface Specification V1.3**
- **HLA Object Model Template V1.3**

Each of these three documents can be accessed via the HLA home page at http://hla.dmso.mil/tech/. In addition, a more detailed description of the lower-level technical issues that must be considered and resolved throughout an HLA federation development can be found in a companion document to the FEDEP called the **FEDEP Checklists**. This document, along with other relevant federation development resources, may be accessed at http://hla.dmso.mil/federation/.

1. PURPOSE

The Department of Defense (DoD) Modeling and Simulation Master Plan [DOD95] calls for the establishment of a DoD-wide High Level Architecture (HLA) for modeling and simulation (M&S) applicable to a wide range of functional applications. The purpose of this architecture is to facilitate interoperability among simulations and promote reuse of simulations and their components.

A named set of simulations interacting via the services of the HLA Runtime Infrastructure (RTI) and in accordance with a common object model and a common HLA rule set is known as an HLA *federation*. The purpose of this document is to describe a high-level process by which HLA federations can be developed and executed to meet the needs of a federation user or sponsor. It is expected that the guidelines provided in this document are generally relevant to and can facilitate the development of most HLA federations.

2. FEDEP MODEL: TOP-LEVEL VIEW

One of the design goals identified early in the development of the HLA was the need for a high degree of flexibility in the process by which HLA applications could be composed to achieve the objectives of particular applications. Because of this basic desire to avoid mandating unnecessary constraints on how HLA applications are constructed, it was recognized that the actual process used to develop and execute HLA federations could vary significantly within or across different user applications. For instance, the types and sequence of low-level activities required to develop analysis-oriented federations is likely to be quite different from those required to develop distributed training exercises. However, at a more abstract level, it is possible to identify a sequence of six very basic steps that all HLA federations will need to follow to develop and execute their federations. Figure 2-1 illustrates each of these steps (along with major inputs/outputs) and is summarized below:

- *Step 1*: *Define Federation Objectives*. The federation user and federation development team define and agree on a set of objectives and document what must be accomplished to achieve those objectives.
- *Step 2*: *Develop Federation Conceptual Model*. Based on the characteristics of the problem space, an appropriate representation of the real world domain is developed.
- *Step 3*: *Design Federation*. Federation participants (federates) are determined, and required functionalities are allocated to the federates.
- *Step 4*: *Develop Federation*. The Federation Object Model (FOM) is developed, federate agreements on consistent databases/algorithms are established, and modifications to federates are implemented (as required).
- *Step 5*: *Integrate and Test Federation*. All necessary federation implementation activities are performed, and testing is conducted to ensure that interoperability requirements are being met.
- *Step 6*: *Execute Federation and Prepare Results*. The federation is executed, outputs are generated, and results are provided.

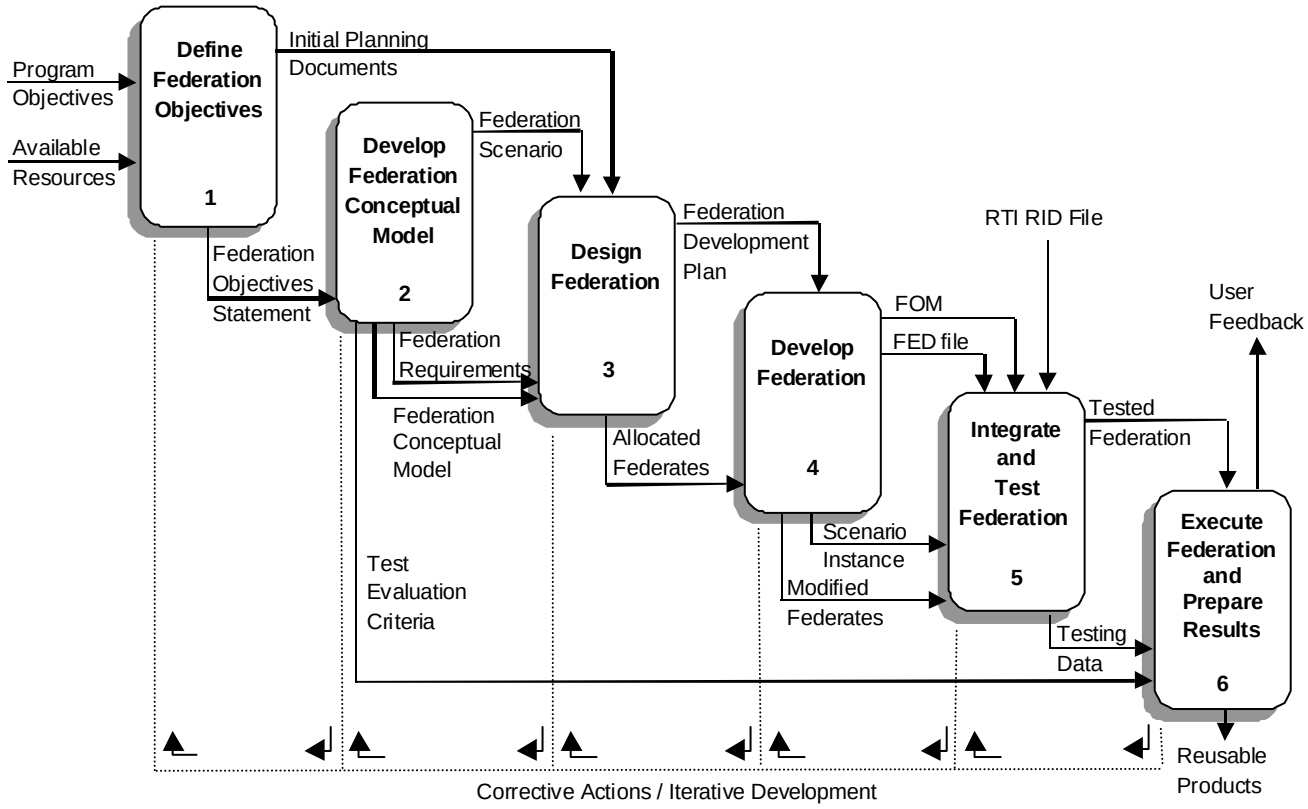

Figure 2-1. Six-Step Process

Since this six-step process can be implemented in many different ways depending on the nature of the application, it follows that the time and effort required to build an HLA federation can also vary significantly. For instance, it may take a federation development team several weeks to fully define the real world domain of interest for very large, complex applications. In smaller, relatively simple applications, the same activity could potentially be conducted in a day or less. Differences in the degree of formality desired in the development process can also lead to varying requirements for federation resources.

Personnel requirements can also vary greatly depending on the scope of the federation application. In some situations, highly integrated teams composed of several individuals may be needed to perform a single role in a large, complex federation, while a single individual may perform multiple roles in smaller applications. Examples of the types of roles individuals can assume in HLA federations include the federation user/sponsor, the federation manager, technologists, security analysts, verification, validation, and accreditation (VV&A) analysts, functional area experts, federation designers, execution planners, federation integrators, federation operators, federate representatives, and data analysts. Some roles (e.g., operators) are

unique to a single activity in the federation development process, while others are more pervasive throughout the process (e.g., federation manager). Since the applicability of a given role (as well as the set of activities it spans) varies from application to application, the activities described in this document specify the roles of individuals only in generic terms.

A major source of variation in how the six-step process is implemented relates to the degree of reuse of existing federation products. In some cases, federations may be developed largely from scratch, using a newly defined set of requirements to identify an appropriate set of federates and to build the full set of federation products needed to support an execution. In other cases, users of federations will have more long-standing requirements and will cumulatively apply their developmental activities for each new application. In these situations, federation developers can often meet new user requirements by reusing a subset of an established core set of federates and defining appropriate modifications to other reusable federation products within their domain (e.g., FOM, planning documents, Federation Execution Planning Workbook [FEPW]). When an appropriate management structure exists to facilitate this type of federation development environment, significant savings can be achieved in both cost and development time.

The remainder of this document describes a structured, systems engineering approach to federation development known as the HLA Federation Development and Execution Process (FEDEP). The six-step process provides a top-level view of the FEDEP, while the FEDEP itself describes a decomposition of each of the six major steps into a set of interrelated lower-level activities and supporting information resources. Since, at this time, the needs of the HLA user community are focused primarily on “first use” applications, the FEDEP currently makes no assumptions about the existence of an established core set of federates or the up-front availability of reusable federation products. Although the intention is to define a comprehensive, generalized framework for HLA federation construction, it is important to recognize that users of this process model will normally need to adjust and modify the FEDEP as appropriate to address the unique requirements and constraints of their particular application area.

3. FEDEP MODEL: DETAILED VIEW

The FEDEP Model describes a high-level framework for the development and execution of HLA federations. The intent of the FEDEP Model is to specify a set of guidelines for federation development and execution that federation developers can leverage to achieve the needs of their application.

The structure of the FEDEP Model is illustrated in Figure 3-1. Data Flow Diagram (DFD) notation is used in Figure 3-1 and throughout this document to represent federation development activities (rounded rectangles), data stores (cylinders), and information flows (arrows) [SIW98]. The federation development activities shown in this diagram are organized into six vertically aligned groupings, each representing a first-level decomposition of one of the six major federation development steps. A mapping of FEDEP activities to the six-step process is also provided in Table 3-1.

The following subsections describe the lower-level activities associated with each of the six major federation development steps and how these activities interrelate. Although many of the activities represented in the FEDEP diagram appear highly sequential, the intention is not to suggest a strict waterfall approach to federation development. Rather, this process illustration is simply intended to highlight the major activities that occur during federation development and approximately when such activities are first initiated relative to other federation development activities. In fact, experience has shown that many of the activities shown in Figure 3-1 as sequential are actually cyclic and/or concurrent, as was indicated earlier in Figure 2-1 via the dotted feedback arrows. Users of the FEDEP should be aware that the activities described in this document, while being generally applicable to most HLA federations, are intended to be tailored to meet the needs of each individual application. For example, FEDEP users should not feel constrained by the federation products explicitly identified in this document, but rather should produce whatever additional documentation is necessary to support their application. Federation developers should generally expect to use and leverage the FEDEP view as a starting point for whatever specific approach to federation development is deemed most appropriate for their application.

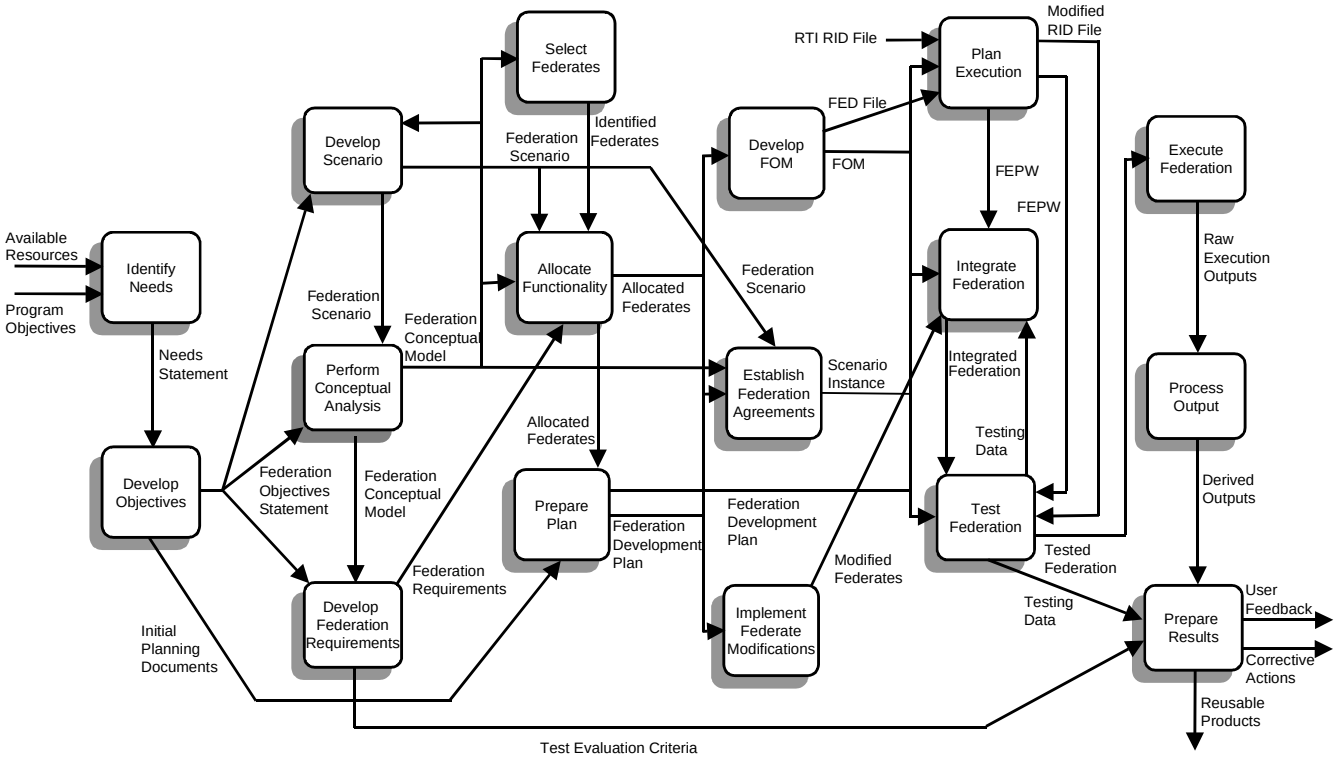

Figure 3-1. Federation Development and Execution Process Model

(1) Define Federation Objectives	(2) Develop Federation Conceptual Model	(3) Design Federation	(4) Develop Federation	(5) Integrate And Test Federation	(6) Execute Federation And Prepare Results
Identify Needs Develop Objectives	Develop Scenario Perform Conceptual Analysis Develop Federation Requirements	Select Federates Allocate Functionality Prepare Plan	Develop FOM Establish Federation Agreements Implement Federate Modifications	Plan Execution Integrate Federation Test Federation	Execute Federation Process Output Prepare Results

Table 3-1. Mapping of FEDEP to Six-Step Process

Step 1: Define Federation Objectives

The purpose of step 1 of the FEDEP is to define and document a set of needs that are to be addressed through the development and execution of an HLA federation and to transform these needs into a more detailed list of specific federation objectives.

Figure 3-2 illustrates the key activities in this step of the FEDEP. In this diagram (and all subsequent diagrams in this section), each individual activity is labeled by a number designation (X.Y) to show traceability between the activity and the step in the six-step process to which the activity is associated (X). The activity number (Y) in these diagrams is intended only as an identifier and does not prescribe a particular ordering. The subsections that follow describe each of these activities.

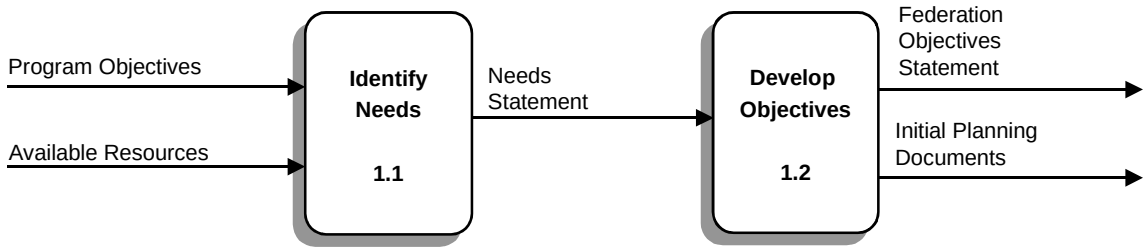

Figure 3-2. Define Federation Objectives (Step 1)

Activity 1.1 Identify Needs

The primary purpose of this activity is to develop a clear understanding of the problem to be addressed by the federation. The needs statement may vary widely in terms of scope and degree of formalization. It should include, at a minimum, high-level descriptions of critical systems of interest, coarse indications of fidelity and required behaviors for simulated entities, key events that must be represented in the federation scenario, and output data requirements. In addition, the needs statement should indicate the resources that will be available to support the federation (e.g., funding, personnel, tools, facilities) and any known constraints that may affect how the federation is developed (e.g., due dates, security requirements). In general, the needs statement should include as much detail and specific information as is possible at this early stage of development.

An explicit and unambiguous statement of federation needs is critical to achieving clear communication of intent among the developers of the federation. Failure to establish a common understanding of the required product can result in costly rework in later stages of the federation development process.

Activity 1.2 Develop Objectives

The purpose of this activity is to refine the needs statement into a more detailed set of specific objectives for the federation. The federation objectives statement is intended as a foundation for generating federation requirements, i.e., translating high-level user/sponsor expectations into more concrete, measurable federation goals. This activity requires close collaboration between the federation user/sponsor and the federation development team to ensure that the resulting objectives are consistent with the stated needs. Examples of the types of information that might be documented as a result of this activity would include the following:

- A prioritized list of measurable objectives for the federation
- A high-level description of key federation characteristics (repeatability, portability, time management approach, etc.)
- A federation development plan showing an approximate schedule and major milestones
- Estimates of needed equipment, facilities, and data
- Operational context constraints or preferences, including friendly/threat/civilian Order of Battle, geographical regions, environmental conditions, and tactics
- Identification of security needs, including probable security level and possible designated approval authority (or authorities, if a single individual is not possible)
- A configuration management plan
- Initial planning documents (e.g., VV&A, test, security)

Early assessments of federation feasibility and risk should also be performed as part of this activity. In particular, certain objectives may not be achievable given practical constraints (such as cost, schedule, availability of personnel or facilities) or even limitations on the state-of-the-art of needed technology. Early identification of such issues and consideration of these limitations and constraints in the Federation Objectives Statement will set appropriate expectations for the federation development effort.

Finally, the issue of tool selection to support scenario development, conceptual analysis, VV&A and test activities, and configuration management should be addressed before the Develop Objectives activity is concluded. These decisions are made by the federation development team on the basis of tool availability, cost, applicability to the given application, and the personal preferences of the participants. The ability of a given set of tools to exchange federation data is also an important consideration.

Step 2: Develop Federation Conceptual Model

The purpose of this step of the FEDEP is to develop an appropriate representation of the real world domain that applies to the federation problem space and to develop the federation scenario. It is also in this step that federation objectives are transformed into a set of highly specific federation requirements that will be used as success criteria during federation testing. Figure 3-3 illustrates the key activities in this step of the FEDEP. The subsections that follow describe each of these activities in detail.

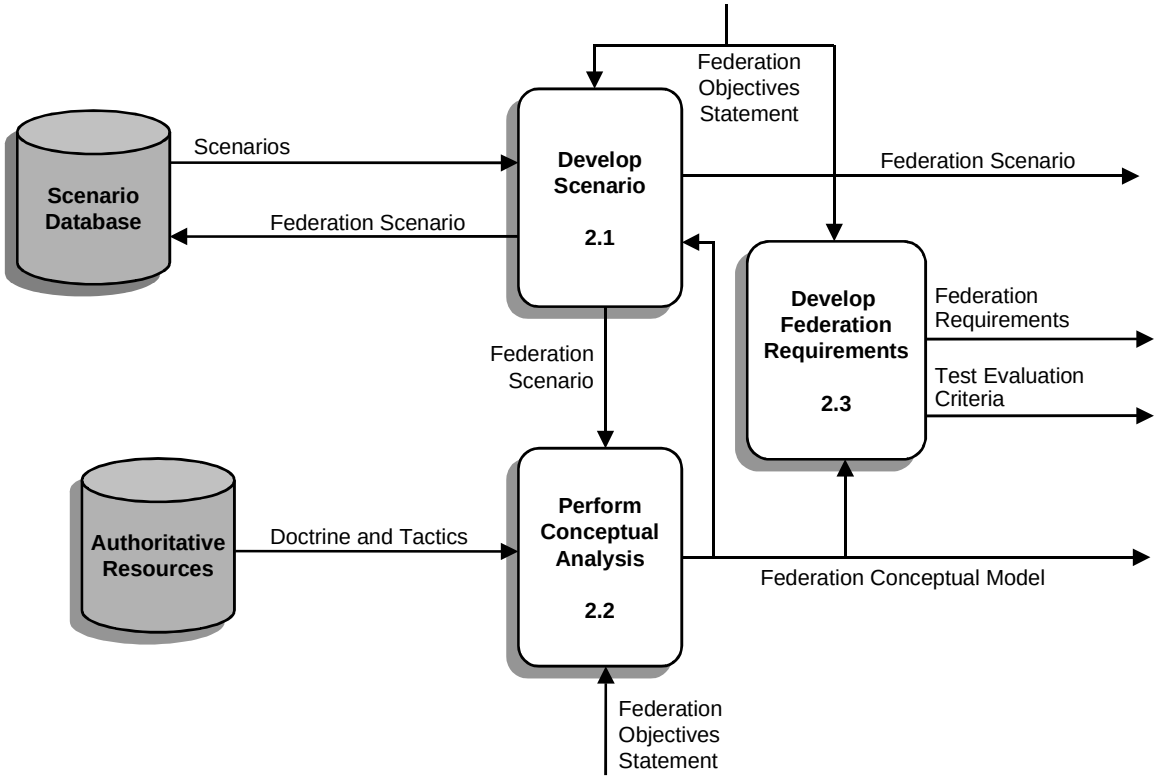

Figure 3-3. Develop Federation Conceptual Model (Step 2)

Activity 2.1 Develop Scenario

The purpose of this activity is to develop a functional specification of the federation scenario. The primary input to this activity is the operational context constraints specified in the objectives statement (step 1), although existing scenario databases may also provide a reusable starting point for scenario development. A federation scenario includes the types and numbers of major entities that must be represented by the federation, a functional description of the capabilities, behavior, and relationships between these major entities over time, and a specification of relevant environmental conditions that impact or are impacted by entities in the federation. Initial conditions (e.g., force laydowns), termination conditions, and specific

geographic regions should also be provided. Multiple scenarios may be developed during this step, depending on the needs of the federation. A single scenario may also support multiple vignettes, each representing a temporally ordered set of events and behaviors. The product of this activity is a federation scenario, which provides a bounding mechanism for conceptual modeling activities.

The presentation style used during scenario construction is at the discretion of the federation developers. Textual scenario descriptions, event-trace diagrams, and graphical illustrations of force laydowns and communication paths all represent effective means of conveying scenario information. Graphical scenario development tools can generally be configured to produce any of these presentation forms. Reuse of existing scenario databases may also facilitate the Scenario Development activity.

Activity 2.2 Perform Conceptual Analysis

During the Conceptual Analysis activity, the federation development team produces a conceptual representation of the intended problem space based on their interpretation of user needs, federation objectives, and the defined environment. The product resulting from this activity is known as a federation conceptual model (see Figure 3-3). The federation conceptual model provides an implementation-independent representation that serves as a vehicle for transforming objectives into functional and behavioral capabilities; the model also provides a crucial traceability link between the federation objectives and the design implementation. This model can be used as the structural basis for many federation design and development activities (including scenario development) and can highlight correctable problems early in the federation development process when properly validated.

The federation conceptual model is a description of the entities and actions that need to be included in the federation in order to achieve all federation objectives. These entities and actions are described without any reference to the specific simulations that will be used in the federation.

From the perspective of Object-Oriented (OO) software system designers, the federation conceptual model is comparable to the notion of a traditional object model. That is, the focus of federation conceptual model development is to identify federation objects, to identify static and dynamic relationships between object classes, and to identify the behavioral and transformational (algorithmic) aspects of each class of object. Static relationships can be expressed as ordinary associations or as more specific types of associations such as generalizations (“is-a” relationships) or aggregations (“part-whole” relationships). Dynamic relationships should include (if appropriate) the specification of temporally ordered sequences of object interactions

with associated trigger conditions. Object characteristics (attributes) and interaction descriptors (parameters) may also be identified to the extent possible at this early stage of design. While other conceptual modeling approaches may be used that are less object-oriented in nature, it is important that the real world domain to be represented in the federation is expressed in terms of objects and object interactions.

Many commercial software tools are readily available that can capture most aspects of the federation conceptual model. Once the federation conceptual model is completed, it needs to be carefully evaluated before the next step (Federation Design) is begun, including a review of key processes and events by the user/sponsor to ensure the adequacy of the domain representation. Revisions to the original federation objectives may be defined and implemented as a result of this feedback.

Activity 2.3 Develop Federation Requirements

As the federation conceptual model is developed, it will lead to the definition of a set of detailed federation requirements. These requirements, based on the original federation objectives (step 1), should be directly testable and should provide the implementation level guidance needed to design and develop the federation. The federation requirements should also explicitly address the issue of fidelity, so that fidelity requirements can be considered during selection of federation participants. In addition, any programmatic or technical constraints on the federation should be refined and described to the degree of detail necessary to guide federation implementation.

Step 3: Design Federation

The purpose of this step of the FEDEP is to identify, evaluate, and select all federation participants (federates), allocate required functionality to those federates, and develop a detailed plan for federation development and implementation. Figure 3-4 illustrates the key activities in this step of the FEDEP. The subsections that follow describe each of these activities in detail.

Activity 3.1 Select Federates

The purpose of this activity is to determine the suitability of individual simulation systems to become members of the federation. This is normally driven by the perceived ability of potential federation members to represent objects, activities, and interactions in the federation conceptual model. In some instances, federation membership may be at least partially predetermined by the federation user/sponsor. Other managerial constraints (e.g., availability,

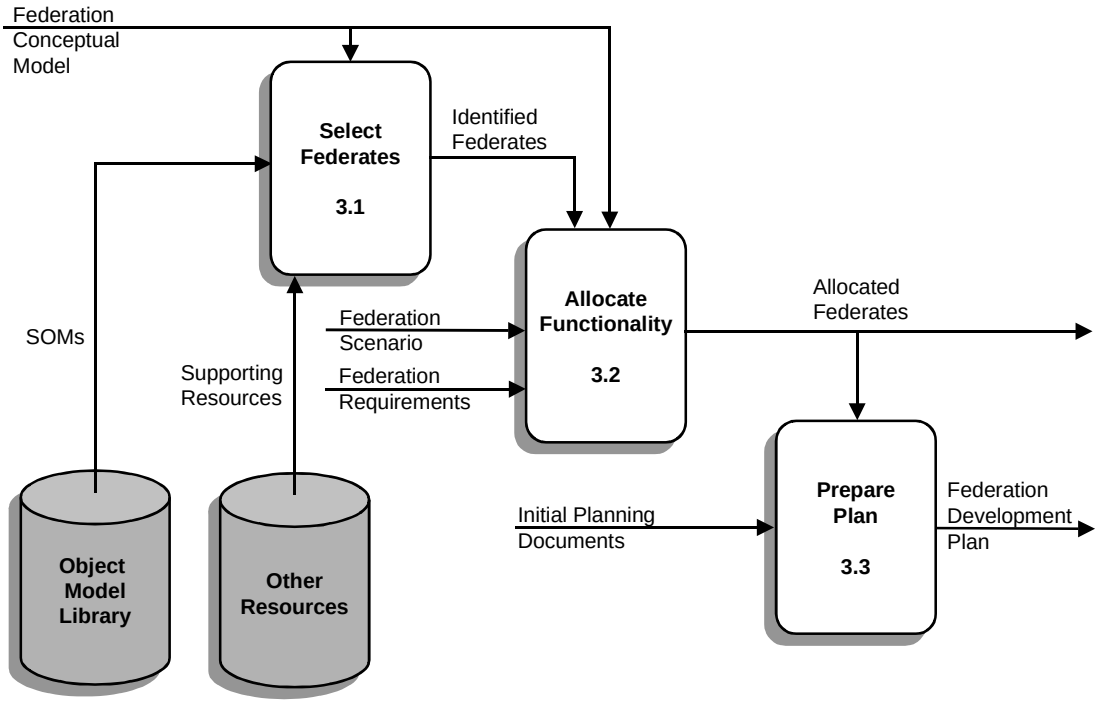

Figure 3-4. Design Federation (Step 3)

security, facilities) and technical constraints (e.g., VV&A status, portability) may also influence the selection of federation members. The searching and browsing features provided by the HLA Object Model Library (OML) may be used to search electronic libraries of Simulation Object Models (SOMs) for candidate simulations, keyed to critical objects and interactions of interest. To support final federate selection decisions, additional information resources (such as design and compliance documents) are generally necessary to fully understand internal simulation representations of required behaviors/activities and other practical aspects of federate utilization.

Activity 3.2 Allocate Functionality

Once all federates have been identified, the next major activity is to allocate the responsibility to represent the entities and actions in the federation conceptual model to the federates. This activity will allow for an assessment of whether the set of selected federates provides the full set of required functionality or whether one or more of the federates will need to be enhanced to meet the federation requirements.

As agreements on assigned responsibilities are negotiated, various federation design trade-off investigations may be conducted as appropriate. Many of these investigations can be considered to be early execution planning and may include technical issues such as time management, federation management, runtime performance, and potential implementation

approaches. The major inputs to this activity include the federation requirements, the federation scenario, and the federation conceptual model (see Figure 3-4). High-level federation design strategies, including modeling approaches and/or tool selection, may be revisited and renegotiated at this time based on inputs from the federates. When the federation represents a modification or extension to a previous federation, new federates must be made cognizant of all previously negotiated agreements within that earlier federation and given the opportunity to revisit pertinent technical issues. For secure federations, efforts associated with maintaining a secure posture during the federation execution can begin at this time. A security point of contact and/or federate security representatives must be designated. These roles may be part time, depending on the size and complexity of the execution. The initial security risk assessment and concept of operations may be refined at this time to clarify the security level and mode of operation.

Activity 3.3 Prepare Plan

Another major activity in step 3 (Federation Design) is to develop a coordinated plan to guide the development, test, and execution of the federation. This requires close collaboration among all federation participants to ensure a common understanding of federation goals and requirements and also to identify (and agree to) appropriate methodologies and procedures based on recognized systems engineering principles. The initial planning documents prepared during development of the federation objectives provides the basis for this activity (see Figure 3-4). The plan should include the specific tasks and milestones for each federate, along with proposed dates for completion of each task.

The plan may also identify the software tools that will be used to support the remaining life cycle of the federation (e.g., RTI version, federation runtime tools, CASE, configuration management, VV&A, testing). For federations with stochastic factors, the plan should include an experimental design to control variability (e.g., variance reduction techniques) and must include determining the number of replications of the execution that are required to achieve desired confidence intervals. These agreements, along with a detailed work plan, must be documented for later reference and possible reuse in other federations.

Step 4: Develop Federation

The purpose of this step is to develop the FOM, modify federates if necessary, and prepare the federation for integration and test (database development, security procedure implementation, etc.). Figure 3-5 illustrates the key activities in this phase of the FEDEP. The subsections that follow describe each of these activities in detail.

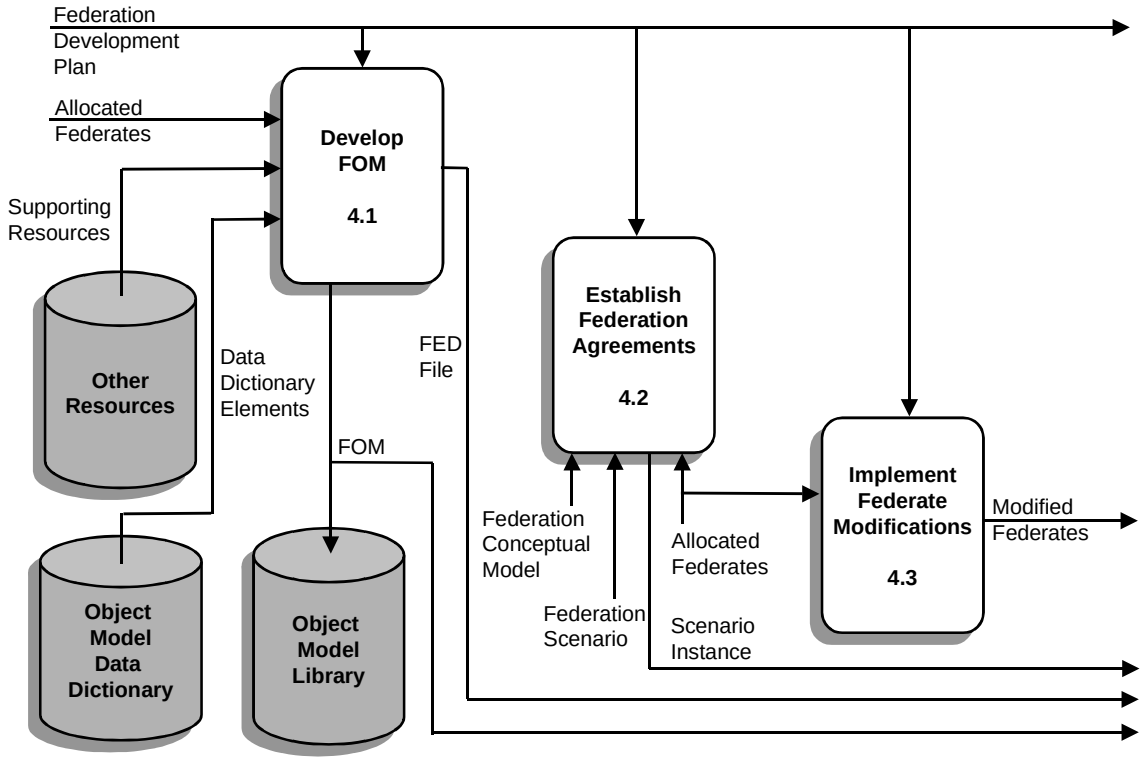

Figure 3-5. Develop Federation (Step 4)

Activity 4.1 Develop FOM

Using the federates identified to meet federation requirements and the allocation of responsibilities for representation of entities and actions in the federation conceptual model across these federates, the FOM is developed to support the data exchanges required among the federates to meet the federation objectives. Several different fundamental approaches can be taken to FOM development, all of which have unique advantages depending on the particular situation. These approaches include the following:

- Construct the FOM from the "bottom up," using the Object Model Data Dictionary (OMDD), the federation scenario, and the federation conceptual model.
- Merge together the SOMs of all participating federates, removing those aspects of the SOMs that do not apply to the domain of interest.
- Begin with the SOM that most closely aligns with the desired FOM, remove those aspects of the SOM that do not apply to the domain of interest, and merge in elements of other SOMs to fully represent the domain.

- Begin with a FOM(s) from a previous, but similar, application. Modify and/or augment as required.
- Begin with a FOM that provides a common frame of reference to a given user community. Remove elements of the FOM that are not required for the application. Modify and/or augment only if necessary.

While each of these last four approaches may represent a somewhat more efficient FOM development strategy (relative to starting entirely from scratch) under certain circumstances, all will require some use and appropriate tailoring of the essential activities described in the current HLA Object Model (OM) Development Process [ITC98]. A summary of these activities is provided in Figure 3-6. Federation security personnel must always maintain knowledge of any classified information associated with applicable entries in each federate's SOM and the implications when this data is combined into a single FOM.

The use of automated tools to facilitate the object model development process is strongly encouraged. As discussed earlier, the HLA OML provides users with access to libraries of reusable object models that can be used either as a starting framework or as individual "piece parts" for a new FOM. In addition, Object Model Development Tools (OMDTs) may be used to modify or extend an existing object model or to build an entirely new object model from scratch. Other OMDT features include consistency checking, syntax checking, Federation Execution Data (FED) file generation, external interfaces to commercial object model development tools, and an on-line users manual.

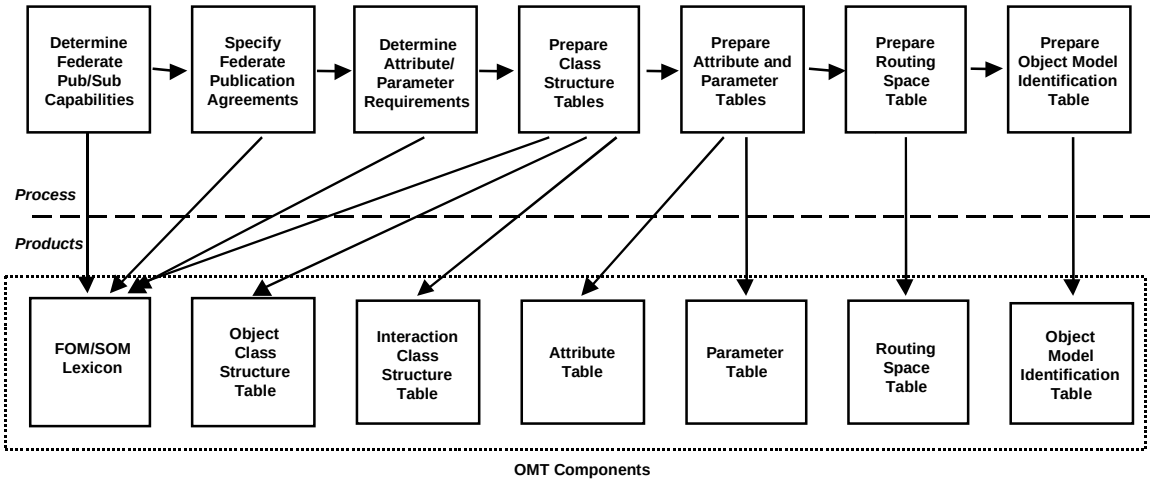

Figure 3-6. FOM Development Process

Activity 4.2 Establish Federation Agreements

Although the FOM defines and documents the full set of data that is exchanged among federates to achieve federation objectives, there are other types of agreements that must be reached among the federates (prior to implementation) that are not necessarily documented in the FOM. Such agreements are necessary to establishing a fully consistent, interoperable distributed simulation environment. For instance, federation members must use the federation conceptual model to gain an understanding and agreement on the behavior of all federation objects and how federation objects will interact with each other during the execution. Requirements for software modifications to selected federates may be identified as a result of these discussions; such requirements must be addressed prior to federation integration activities. Also, agreements must be reached as to the databases and algorithms that must be common (or at least consistent) across the federation to guarantee valid interactions ("fair fights") among all federation participants. For instance, a consistent federation-wide view of simulated environmental features and phenomena is critical in order for objects owned by different federates to interact and behave in a realistic fashion.

Once all authoritative data sources that will be used in support of the federation have been identified, the actual data stores are used to transition the functional description of the scenario (developed in step 2; see Figure 3-3) to an executable scenario instance (or set of instances). The product of this activity permits federation testing to be conducted directly within the context of the domain of interest and also drives the execution of the federation later in the FEDEP.

Finally, certain operational issues must be addressed and resolved among the members of the federation. For instance, agreements on federation initialization procedures, synchronization points, and save/restore policies are all necessary to ensure proper operation of the federation. In addition, federates should revisit the federation requirements at this time to ensure a common understanding as to the data that must be gathered during execution to produce user/sponsor-specified outputs and the strategy that will be used to collect that data.

Activity 4.3 Implement Federate Modifications

The purpose of this activity is to implement whatever modifications are necessary to the federates to ensure that they can represent assigned objects and associated behaviors as described in the federation conceptual model (step 2), produce and exchange federation data with other federates as defined by the FOM, and abide by the established federation agreements. This may require internal modifications to the federate to support assigned domain elements, or it may

require modifications or extensions to the federate's HLA interface to support new FOM data structures or HLA services that were not supported in the past. In some cases (for non-HLA compliant federates) it may even be necessary to develop an HLA interface for the federate. In this situation, the federate must consider both the resource (e.g., time, cost) constraints of the immediate application as well as longer-term reuse issues in deciding the best overall strategy for completing the federate interface.

Step 5: Integrate and Test Federation

The purpose of this step of the FEDEP is to plan the federation execution, establish all required interconnectivity between federates, and test the federation prior to execution. Figure 3-7 illustrates the key activities in this step of the FEDEP. The subsections that follow describe each of these activities.

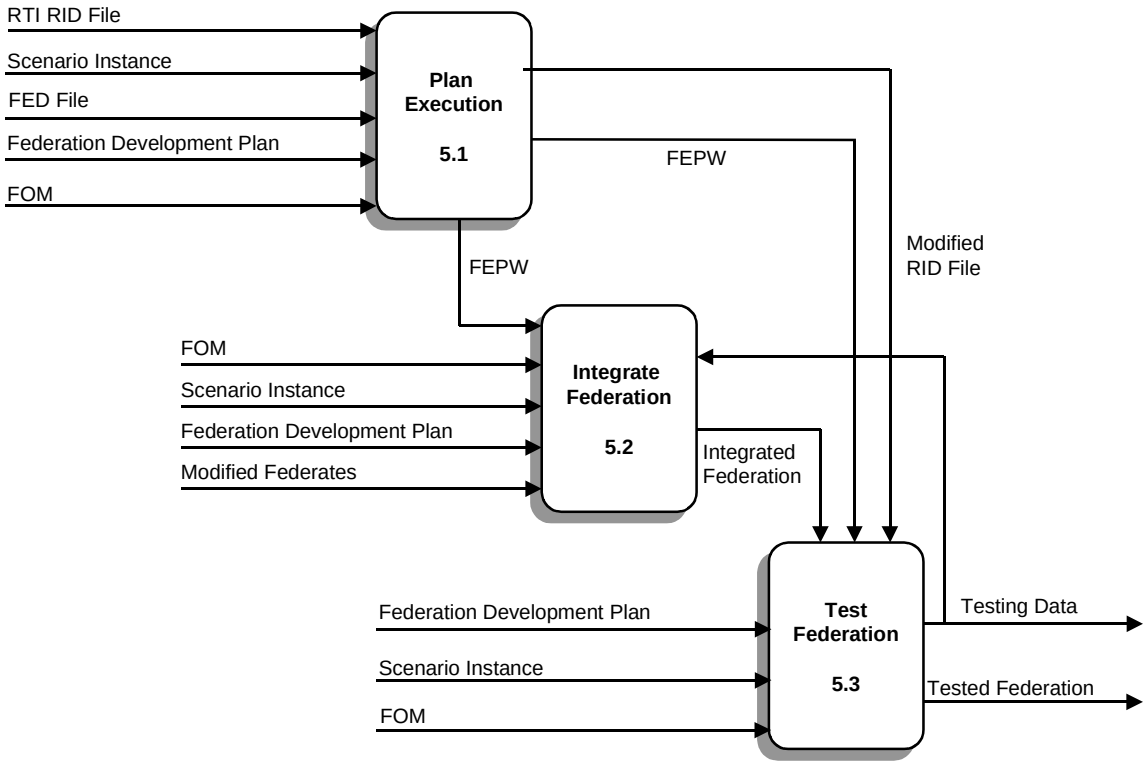

Figure 3-7. Integrate and Test Federation (Step 5)

Activity 5.1 Plan Execution

The purpose of this activity is to define and develop the full set of information required to support an HLA federation execution. In addition to refining test and VV&A plans, the main activity in this step is to document the template of information described in the Federation

Execution Planners Workbook (FEPW). This workbook provides a common, structured mechanism for describing the performance requirements of the federation and for defining other essential characteristics of HLA federations, including federate performance, host requirements, and network requirements. Collectively, the tables provided in this workbook define all of the execution-specific information needed by a federation developer to test and operate the federation. The completed workbook, taken together with the FOM and associated FED file, provides the necessary foundation to transition into the integration and testing phase of federation development.

An additional activity in this step for secure federations is to develop a security test and evaluation plan. This task requires reviewing and verifying the security work accomplished thus far in the federation development and finalizing the technical details of security design, such as information downgrading rules, formalized practices, etc. This plan represents an important element of the necessary documentation set for the federation.

Finally, in situations in which federation performance is an especially critical issue, it may be desirable to modify the RTI Initialization Data (RID) file associated with the specific RTI implementation being used in the federation. Although the need for RID file modifications will be unnecessary in most federations, performance enhancements may be achievable in some circumstances.

Activity 5.2 Integrate Federation

The purpose of this activity is to bring all of the federation participants into a unifying operating environment. This requires that all federate hardware and software assets are properly installed and interconnected in a configuration that can satisfy all FOM data interchange requirements and federation agreements. The federation development plan specifies the methodology used in this activity for federation integration, and the federation scenario instance provides the necessary context for integration activities.

Federation integration is normally performed in close coordination with federation testing. Iterative “test-fix-test” approaches are used quite extensively in practical applications and have been shown to be quite effective.

Activity 5.3 Test Federation

The purpose of this activity is to test that all of the federation participants can interoperate to the degree required to achieve federation objectives. Three levels of testing are defined for HLA applications:

Federate Testing: In this activity, each federate is tested to ensure that the federate software correctly implements the federation requirements as documented in the HLA FOM, FEPW, and any other federation operating agreements.

Integration Testing: In this activity, the federation is tested as an integrated whole to verify a basic level of interoperability. This testing primarily includes observing the ability of the federates to interact correctly with the RTI and to exchange data as described by the FOM.

Federation Testing: In this activity, the ability of the federation to interoperate to the degree necessary to achieve federation objectives is tested. This includes observing the ability of federates to interact according to the defined scenario and to the level of fidelity required for the application. This activity also includes security certification testing if required for the application.

Procedures for conducting federation testing must be agreed upon by all federation participants and documented in a formal test plan. Data collection plans should be exercised during the testing phase to ensure that the data needed to support the federation objectives is being accurately collected and stored. The HLA Management Object Model (MOM) may be used during integration/federation testing to provide useful information on the operation of the RTI, individual federates, and the integrated federation.

The desired output from this activity is a set of testing data that, once evaluated, indicates that execution of the federation can commence. If early testing data uncovers obstacles to successful federation integration, federate or federation developers must take corrective actions. In many cases, these corrective actions simply require a relatively minor software fix (or series of fixes) or minor adjustment to the FOM. However, testing may also uncover more serious software or interoperability problems. In these cases, options may need to be identified, with their associated cost and schedule estimates (including security and VV&A implications), and should be discussed with the federation user/sponsor before corrective action is taken.

Finally, whenever a federate has modified its HLA interface to meet federation requirements, that federate should be tested (or retested) for compliance to the HLA. Although this task may be performed at this time, compliance testing may also be performed as a post-federation activity.

Step 6: Execute Federation and Prepare Results

The purpose of this step of the FEDEP is to execute the federation, process the output data from the federation execution, report results, and archive reusable federation products. Figure 3-8

illustrates the key activities in this step of the FEDEP. The subsections that follow describe each of these activities.

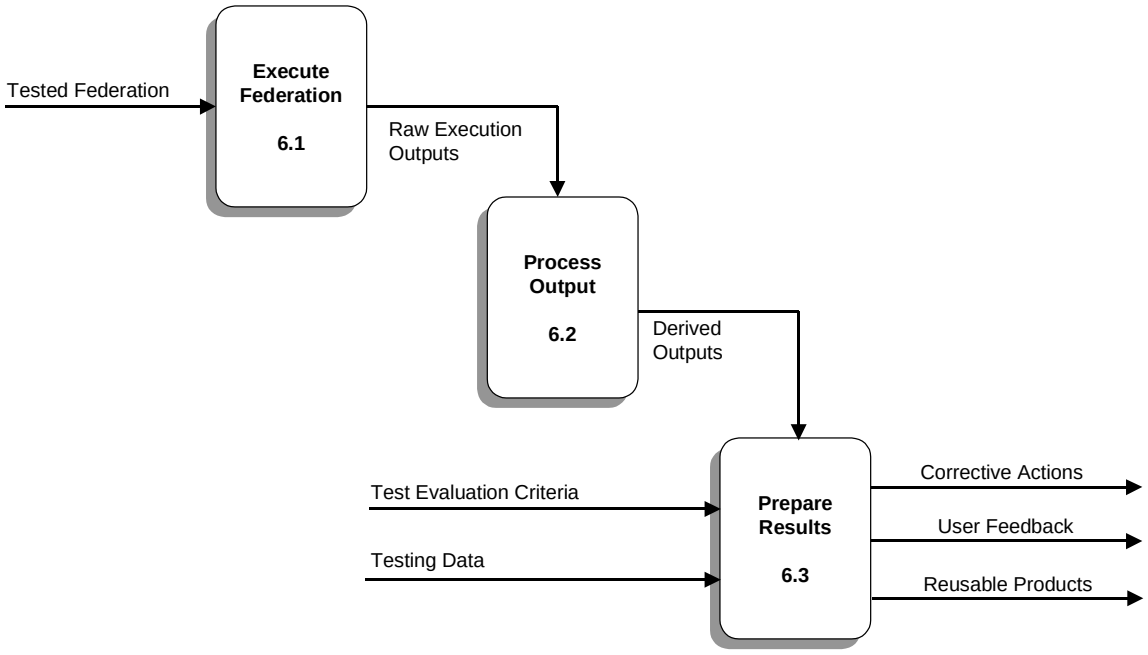

Figure 3-8. Execute Federation and Prepare Results (Step 6)

Activity 6.1 Execute Federation

The purpose of this activity is to exercise all federation participants as an integrated whole to generate required outputs and thus achieve stated federation objectives. The federation must have been tested successfully before this activity can begin. Besides executing the federation in a coordinated fashion over time, this activity principally includes execution management and data collection. Execution management involves controlling and monitoring the execution via specialized software tools (as appropriate). Execution can be monitored at the hardware level (e.g., CPU usage, network load), or software operations can be monitored for individual federates or across the full federation. Data collection is focused on assembling the desired set of outputs and on collecting whatever additional supporting data is required to assess the validity of the federation execution. In some cases, data is also collected to support replays of the federation execution (i.e., "playbacks"). Essential federation data may be collected via databases in the federates themselves or can be collected via specialized data collection tools directly interfaced to the RTI. The particular strategy for data collection in any particular federation is entirely at the discretion of the federation development team.

For secure federations, strict attention must be given to maintaining the security posture of the federation during execution. A clear concept of operations, properly trained security personnel, and strict configuration management will all facilitate this process. It is important to remember that authorization to operate (accreditation) is usually granted for a specific configuration of federates. Any change to the federates or federation composition will certainly require a security review and may require some or all of the security certification tests to be redone.

Activity 6.2 Process Output

The purpose of this activity is to post-process (as necessary) the output collected during the federation execution. Such post-processing normally requires the application of appropriate statistical measures and other data reduction methods to transform raw data into derived results. Commercial or government off-the-shelf (COTS/GOTS) statistical analysis tools and other post-processing tools are often applicable here.

Activity 6.3 Prepare Results

This activity is composed of two main tasks. In the first task, the derived results from the previous activity are evaluated to determine if all federation objectives have been met. This requires a retracing of execution results to the measurable set of federation requirements originally generated during Conceptual Analysis (step 2) (and refined in subsequent steps). In the vast majority of cases, any impediments to fully satisfying federation requirements have already been identified and resolved much earlier during the federation development and integration phases. Thus, for well-designed federations, this task is merely a final check. In those rare cases in which certain federation objectives have not been fully met at this late stage of the overall process, corrective actions must be identified and implemented. This may necessitate revisiting previous steps of the FEDEP and regenerating federation results.

The second task in this activity, assuming all federation objectives have been achieved, is to store all reusable federation products in an appropriate archive and, if appropriate, make them available through systems such as the Modeling and Simulation Resource Repository (MSRR). At a minimum, this would include storing the FOM and any modifications to the SOMs of federation participants in the OML. However, there are several other federation products that may also be reusable, such as new OMDD entries, the federation scenario, and the federation conceptual model. In fact, it may be advantageous in some instances to capture the full set of federation products required to reproduce the federation execution. Determination of which

federation products have potential for reuse in future applications is at the discretion of the federation development team.

4. CONCLUSION

This document has provided a view of the federation development and execution process. Currently, this model represents the best practices available to the HLA community. The FEDEP is an easily tailored model and is offered as guidance to HLA federation developers. As additional experience is accrued in building HLA applications, the FEDEP will leverage this knowledge and evolve accordingly.

In the longer term, the FEDEP is expected to serve as a framework for the development of alternative, more detailed views of the federation development process that may better satisfy the needs of specific communities. Such views can provide implementation level guidance to "hands-on" federation builders without the need to interpret and customize the more generalized FEDEP activity descriptions to a particular domain. Federation developers are encouraged to perform these types of adaptations whenever appropriate.

Acronyms

COTS	Commercial Off-the-Shelf
DFD	Data Flow Diagram
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
FED	Federation Execution Data
FEDEP	Federation Development and Execution Process
FEPW	Federation Execution Planners Workbook
FOM	Federation Object Model
GOTS	Government Off-the-Shelf
HLA	High Level Architecture
M&S	Modeling & Simulation
MOM	Management Object Model
MSRR	Modeling and Simulation Resource Repository
OM	Object Model
OMDD	Object Model Data Dictionary
OMDT	Object Model Development Tool
OML	Object Model Library
OMT	Object Model Template
OO	Object Oriented
RID	RTI Initialization Data
RTI	Runtime Infrastructure
SOM	Simulation Object Model
VV&A	Verification, Validation, and Accreditation

References

[DOD95] Department of Defense, Under Secretary of Defense (Acquisition and Technology) (USD (A&T)), *DoD Modeling and Simulation (M&S) Master Plan*, Washington, DC, October 1995.

[ITC98] Defense Modeling and Simulation Office, *HLA Object Model Development Process and Supporting Tools*, International Training and Education Conference (ITEC) Briefing, April 1998.

[SIW98] Scrudder R., Waite W., Richardson M., and Lutz R., *Graphical Presentation of the Federation Development and Execution Process*, Simulation Interoperability Workshop, Fall 1998.

Comments

Comments on this document should be sent by electronic mail to the Defense Modeling and Simulation Office HLA mailing address (hla@msis.dmso.mil). The subject line of the message should include the FEDEP section number referenced in the comment. The body of each submittal should include (1) the name and electronic mailing address of the person making the comment (separate from the mail header), (2) reference to the portion of this document that the comment addresses (by page, section number, and paragraph number), (3) a one-sentence summary of the comment and/or issue, (4) a brief description of the comment and/or issue, and (5) any suggested resolution or action to be taken.